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Automated hyperspectral remote sensing from ships-of-opportunity in the Baltic Sea

progress, system performance, and new services

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supported by BONUS

stefansimis

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Redundancy is important

Observing phytoplankton biomass from multi-source observations

Platform	Observed layer	Spatio-temporal coverage	Observed quantity	Signal source
Earth Observing Satellites	Variable up to 15 m	Whole system, up to daily	Reflectance bands	Pigment absorption, particle scattering, sun-induced fluorescence
Ferryboxes	3-5 m	Transect 1-2/week	Fluorescence	In-vivo pigments
Profilers	Column	Point, hourly	Fluorescence	In-vivo pigments

Extrapolating from depth-resolved fixed stations to the satellite field-of-view is compromised when vertical mixing in the sea, atmospheric properties, or the proportionality of the observed quantities are spatially heterogeneous or poorly characterized

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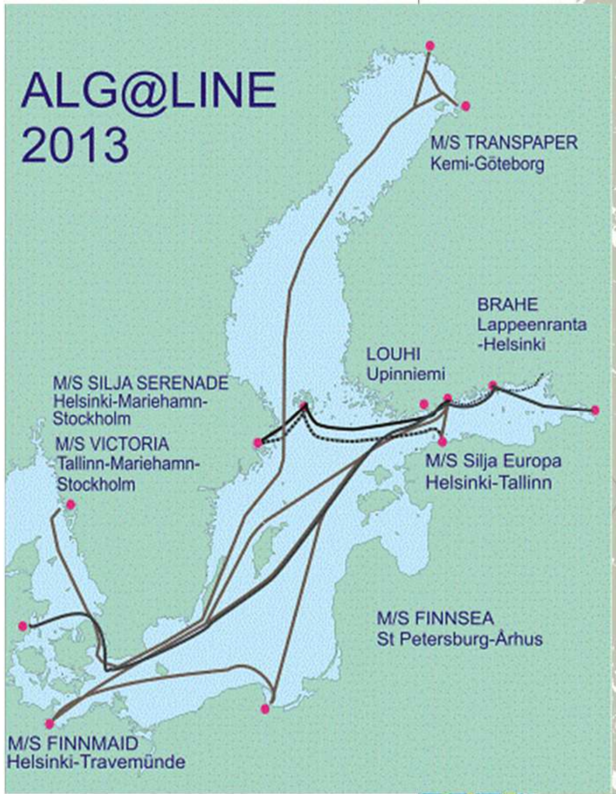

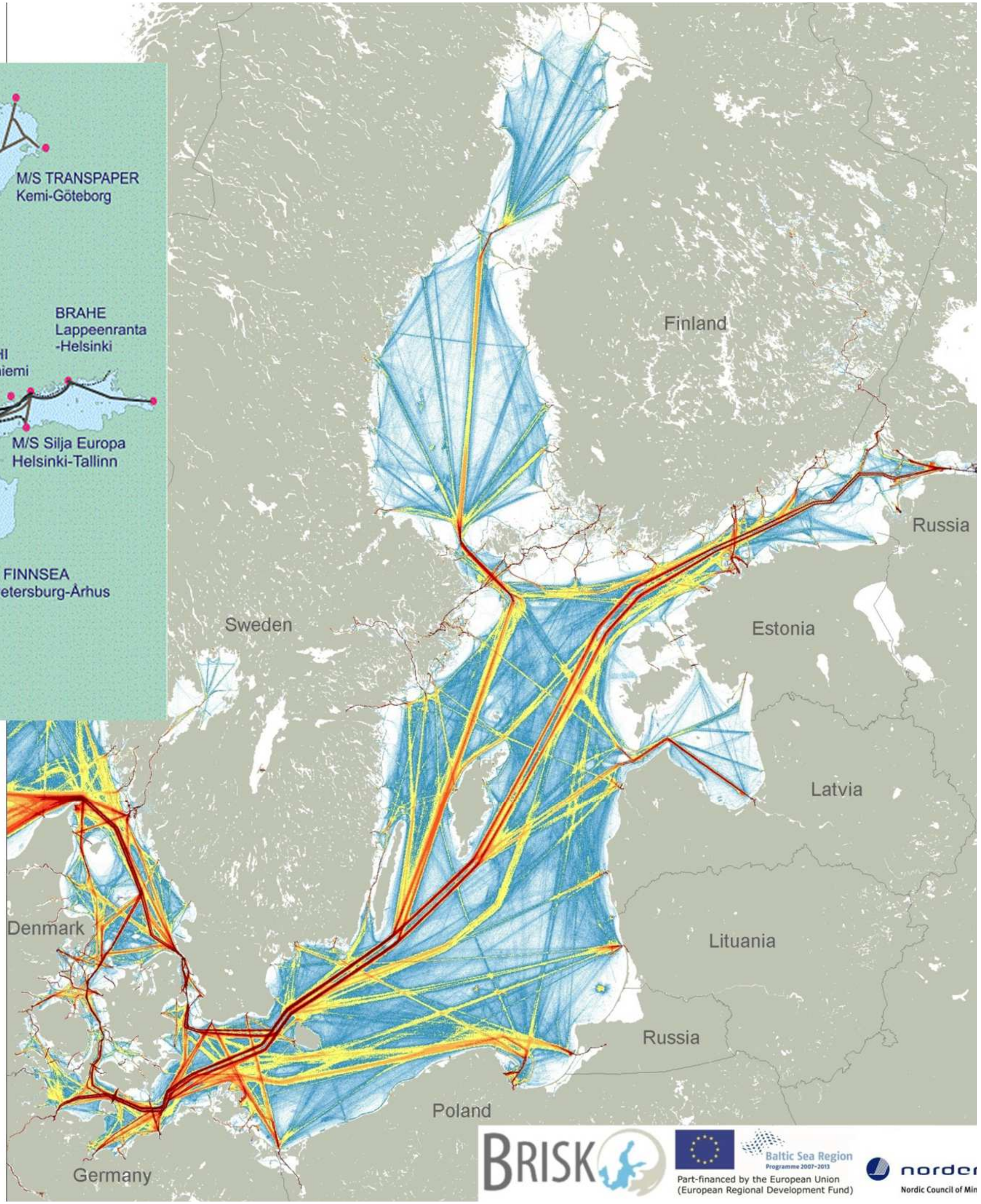

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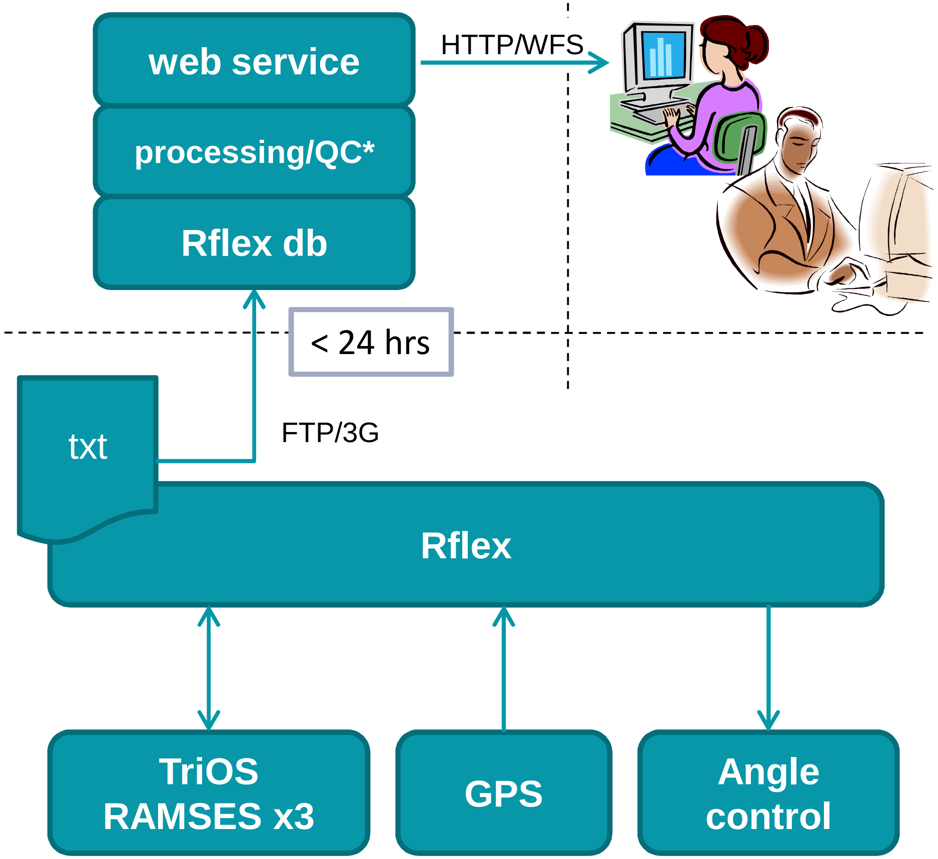
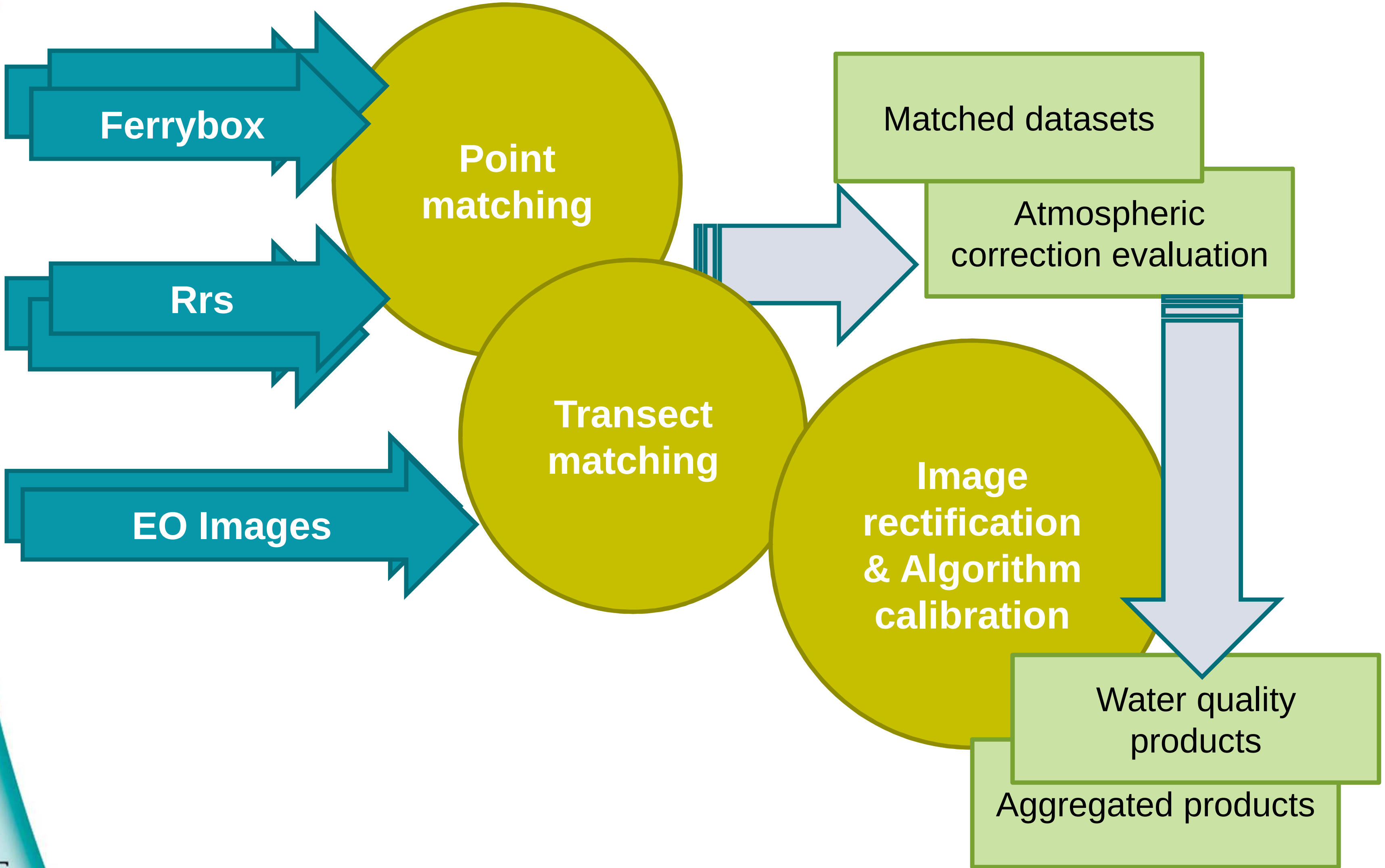
Bridging the divide between in-water and remote observations with in-situ remote-sensing reflectance (R_{rs})



cost per unit
25kEUR / 20k GBP

**Simis and Olsson 2013, RSE*
PROTOOL, WaterS, ESA Balmon, ***BONUS FerryScope***

Near-real time value-adding chain



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FerryScope

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FerryScope progress

Summer 2014:

- 2nd Rflex set installed on MS *Transpaper*
- Optimizing connectivity (delivery usually < 1d)
- Rflex R_{rs} web service configuration

Winter -> 2015

- Implementation in CalValus
- Demonstration products
- Services for matchups, AC confidence, blooms..
- *User-driven development*

2016

- Operational phase.
- Sentinel-3 launch postponed for the last time

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Implementation

Starboard on M/S *Finnmaid* (Finnlines)

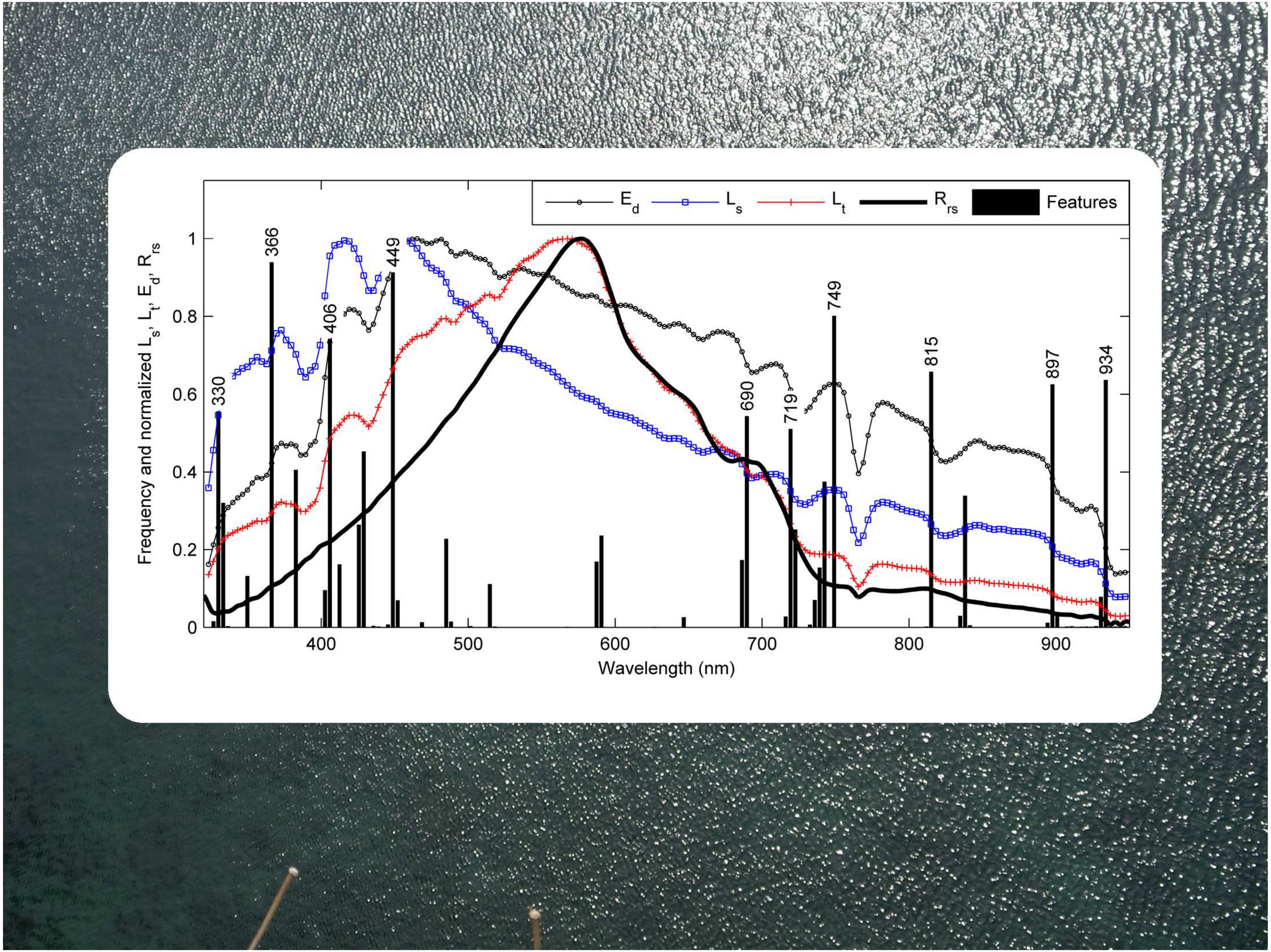
Rflex:
Water-leaving Radiance (L_t)
Sky radiance (L_s)
Downwelling irradiance (E_d)
L sensors on rotating platform to avoid sun glint

Hyperspectral, 320-950 nm
15-s interval

Matched with flow-through observations in post-processing

Rrs resolved with iterative algorithm (correct surface reflectance) -> poor measurements flagged

**Simis and Olsson 2013, RSE*



E_d
L_s
L_t
R_rs
Features
Frequency and normalized L_s, L_t, E_d, R_rs
Wavelength (nm)
0
0.2
0.4
0.6
0.8
1
400
500
600
700
800
900
330
366
406
449
690
719
749
815
897
934

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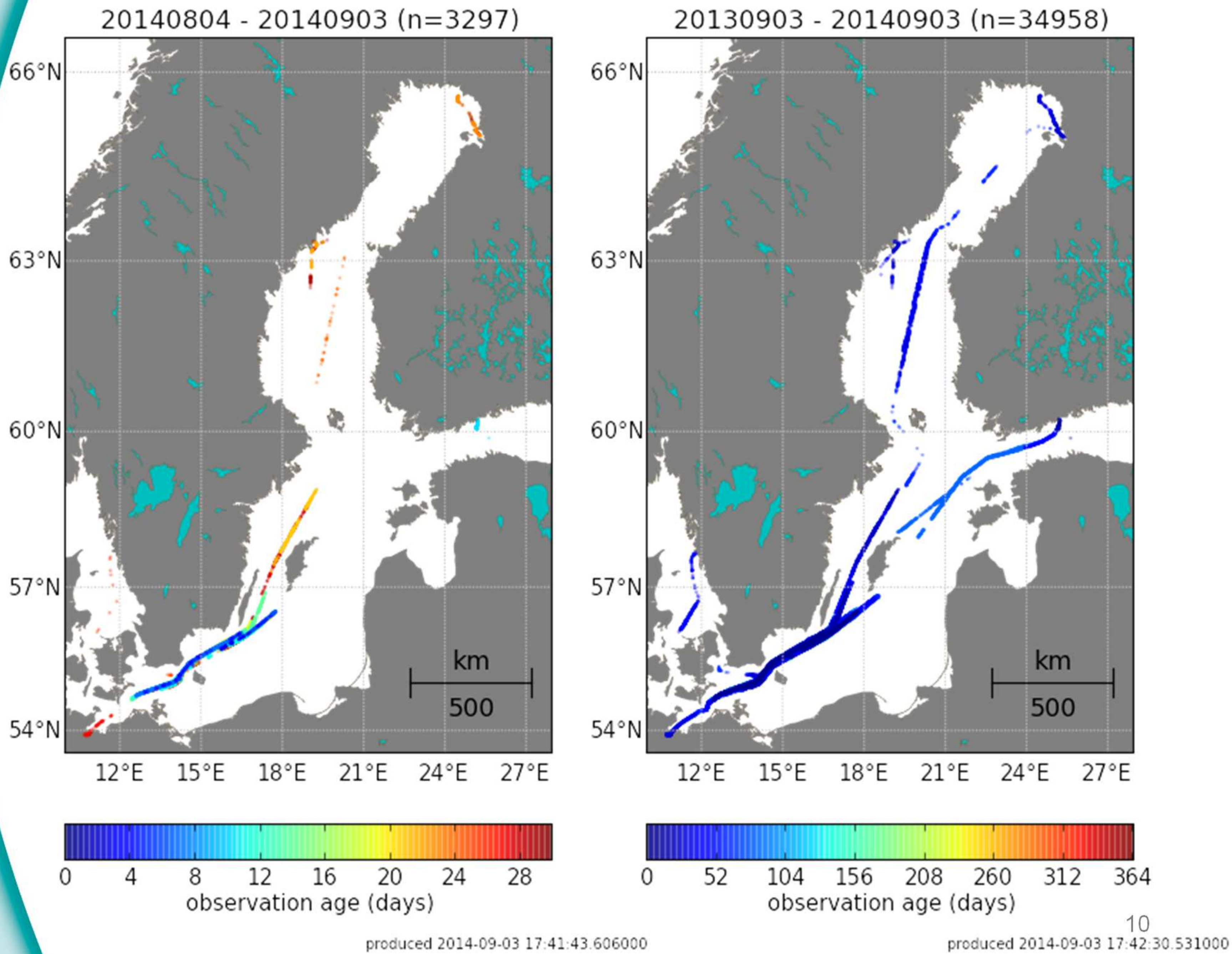

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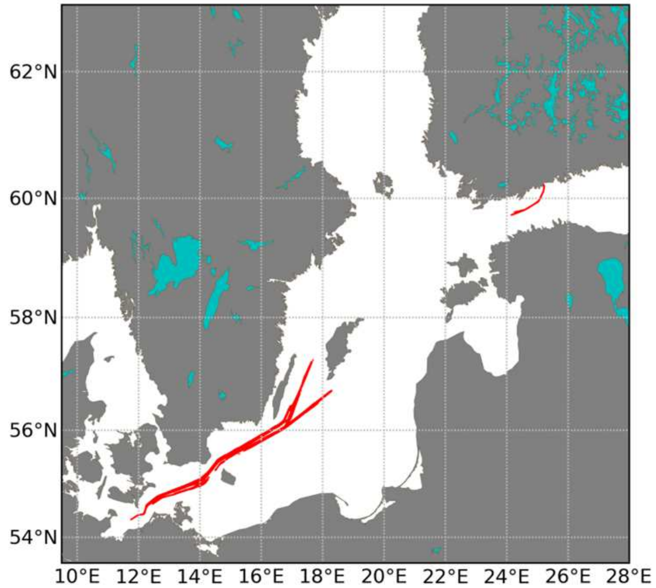
First period of autonomous use, sanity checks

July-September 2013

- 'Normal' bloom year, some surface accumulations
- Rflex on MS *Finnmaid* (Helsinki-Travemunde)
- 23025 R_{rs} spectra passed QC
- Q: do we get consistent results?



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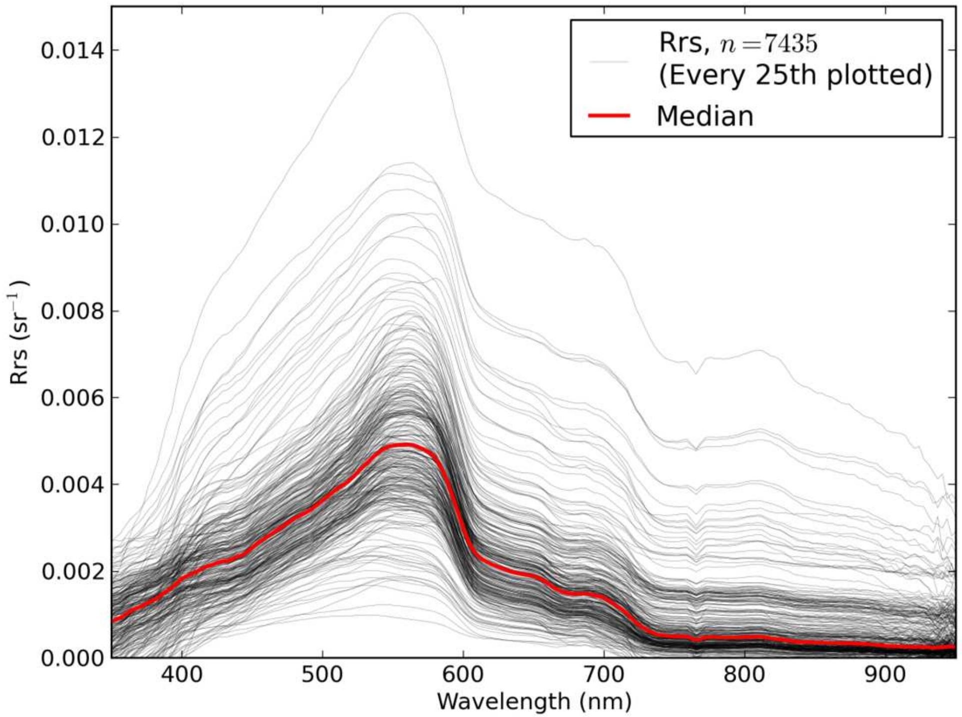
Checking consistency in R_{rs} with a spectral classification

Baltic Sea Rrs has a conservative shape: dominant CDOM and water absorption leave a green R_{rs} peak

R400<R580>R800

= no anomalies



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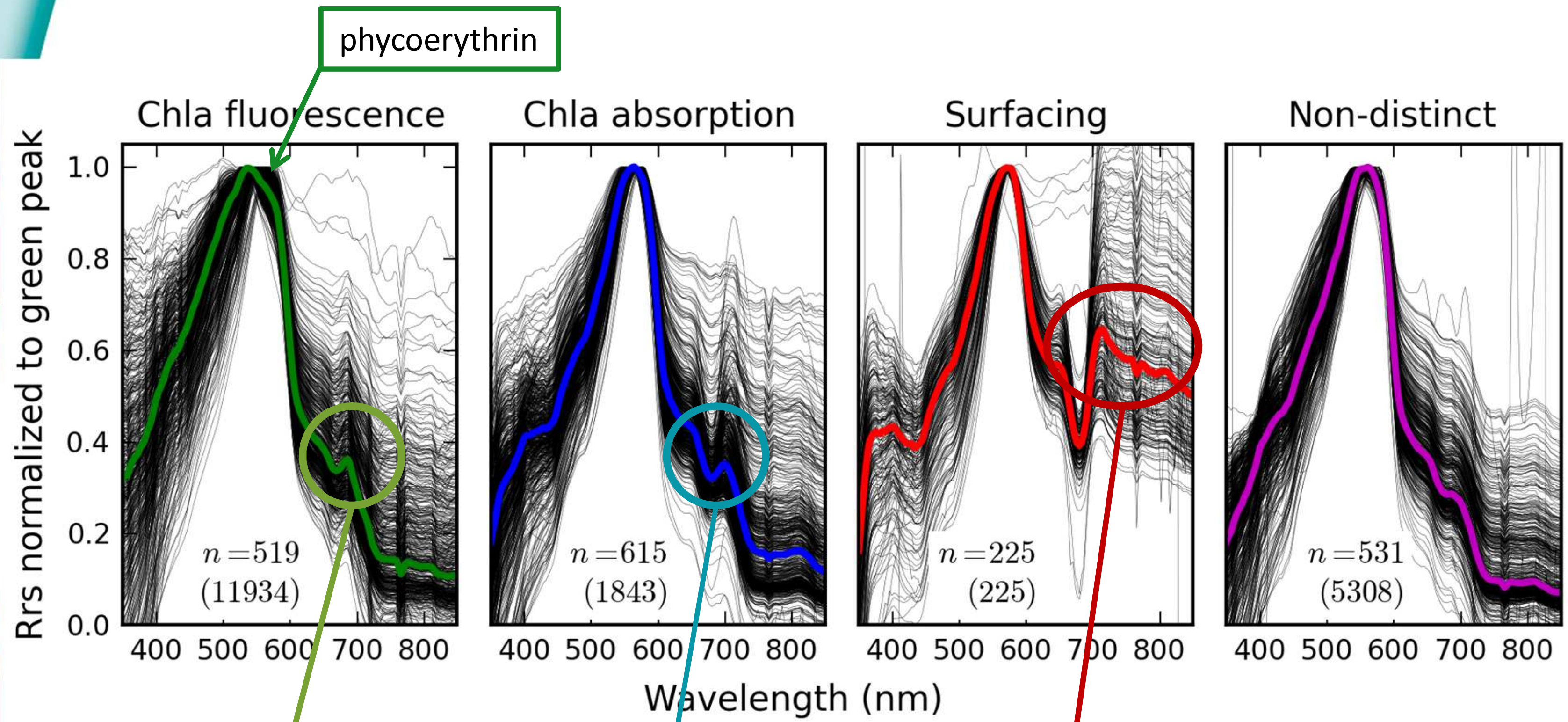
Rule-based spectral classification



Chl-a fluorescence > absorption:
$R_{400}<R_{580}>R_{685}>R_{675}>R_{800}$

Near-infrared anomaly
$R_{400}<R_{580}>R_{675}<R_{800}$

Chl-a absorption > fluorescence
$R_{400}<R_{580}>R_{675}<R_{700}>R_{800}$
& $R_{685}<R_{700}$

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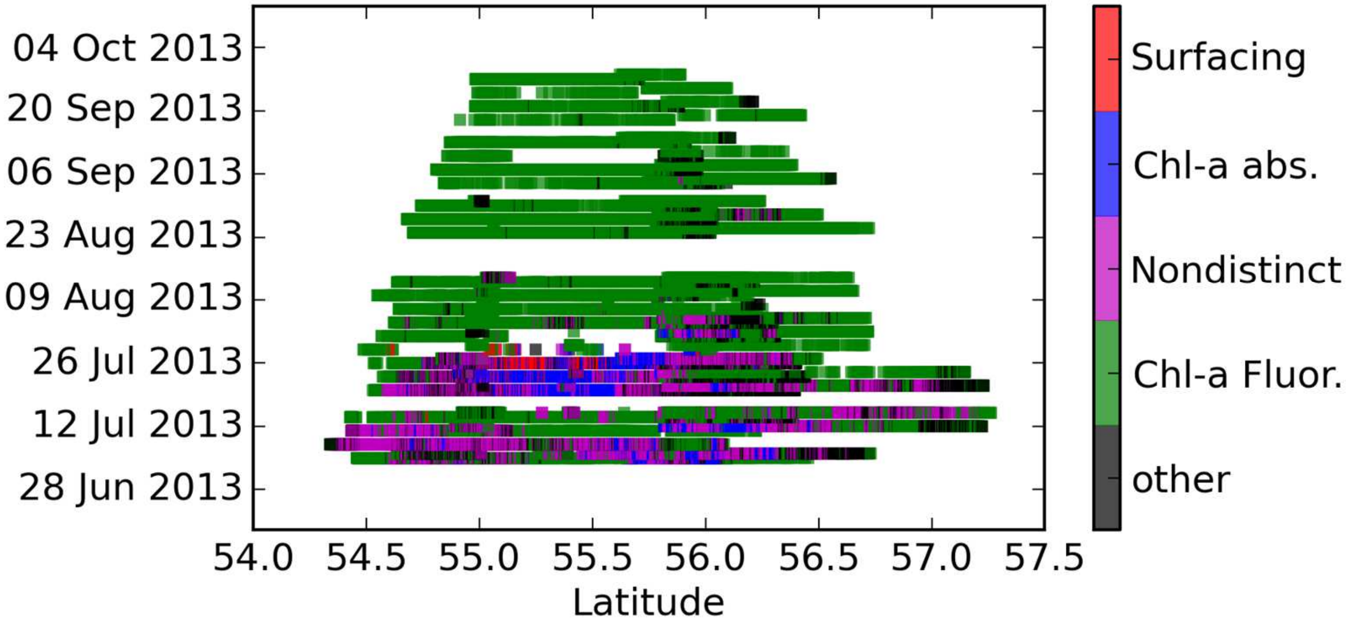
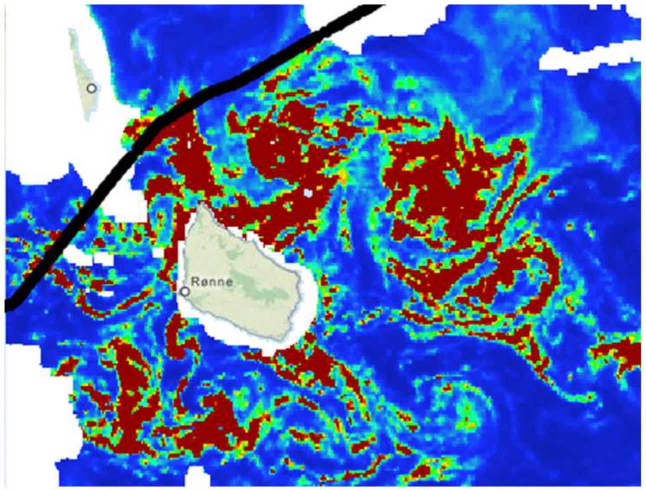
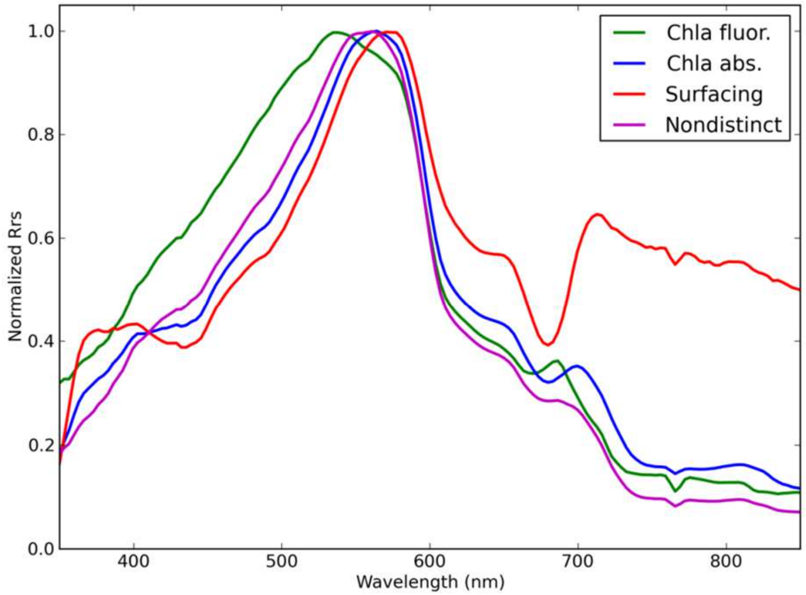




26 July 2013, MODIS



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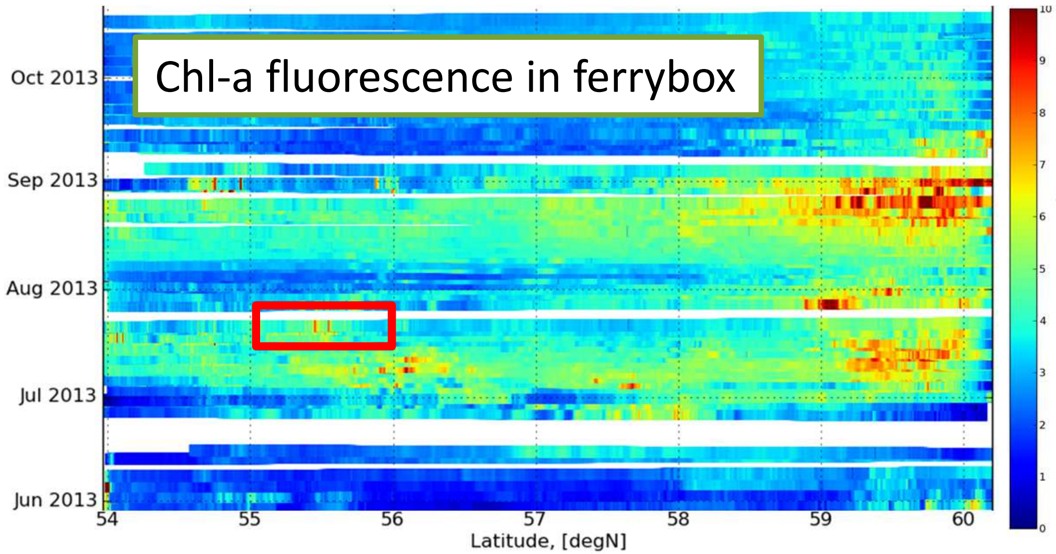
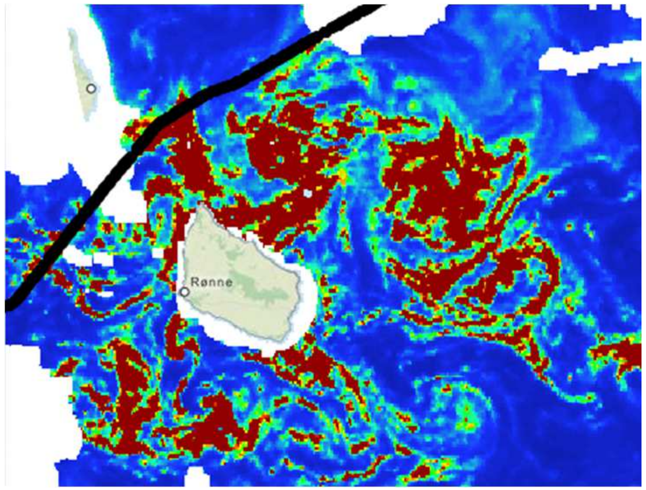
R_{rs} vs Ferrybox: surface accumulations

MODIS shows extreme values on 26 July 2013, suggests surface bloom





26 July 2013, MODIS

No enhanced Chl-a fluorescence at ferrybox intake depth (5 m) throughout bloom period -> biomass in shallow layer, or pigments not fluorescing

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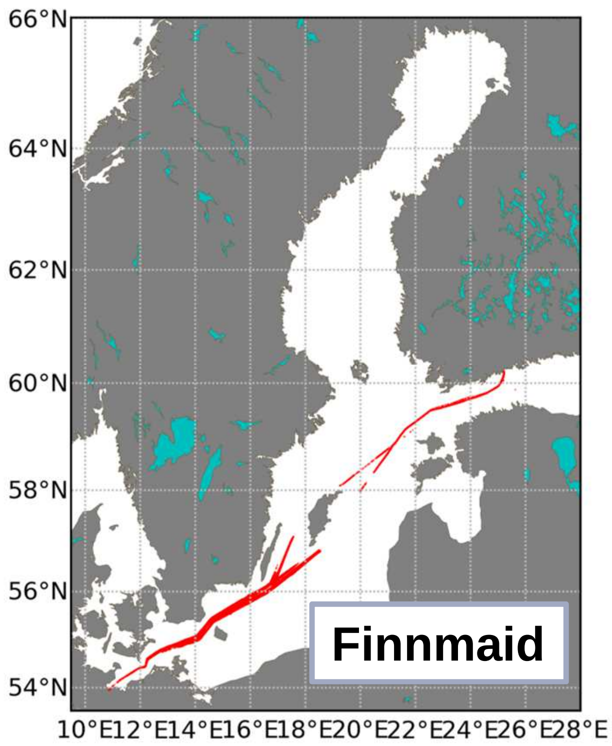
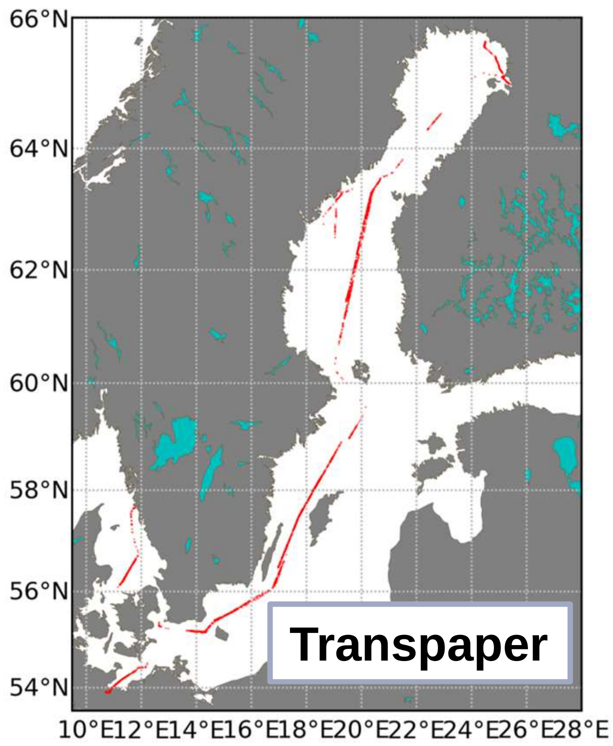
2014

April 2014 – present

- Main objective: implementing sustained service
- First attempt at spring bloom observations (low sun angles!)
- Rflex on MS *Finnmaid* and MS Transpaper (> July, with SMHI)





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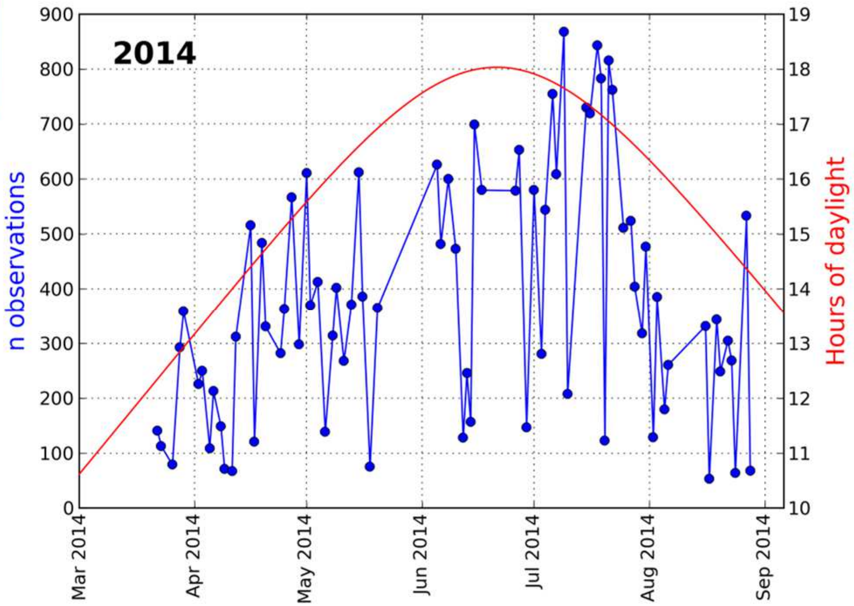
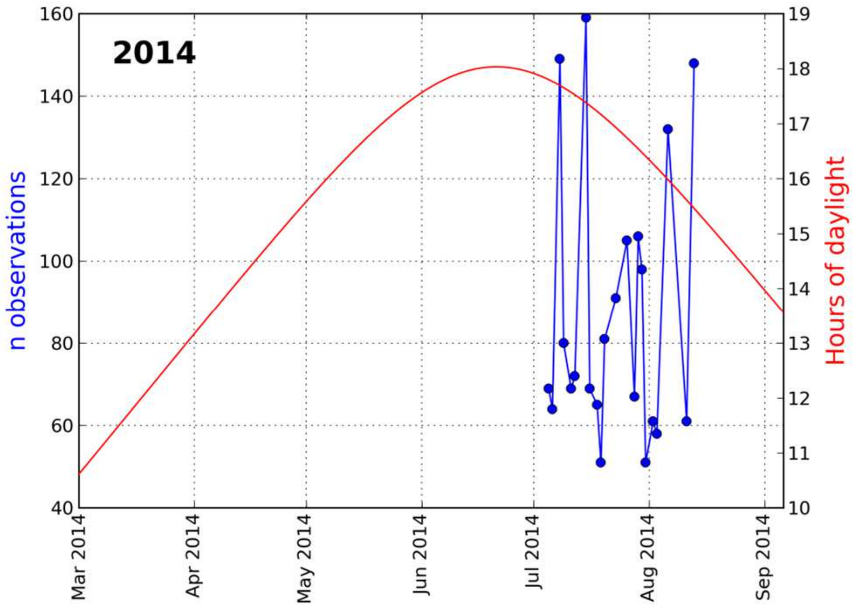


Finnmaid



Transpaper

Obs/day for Transpaper significantly lower than for Finnmaid:

- Sensor intercalibration results not yet in Rrs processing
- Lower sun elevation and clear, dark water of Gulf of Bothnia

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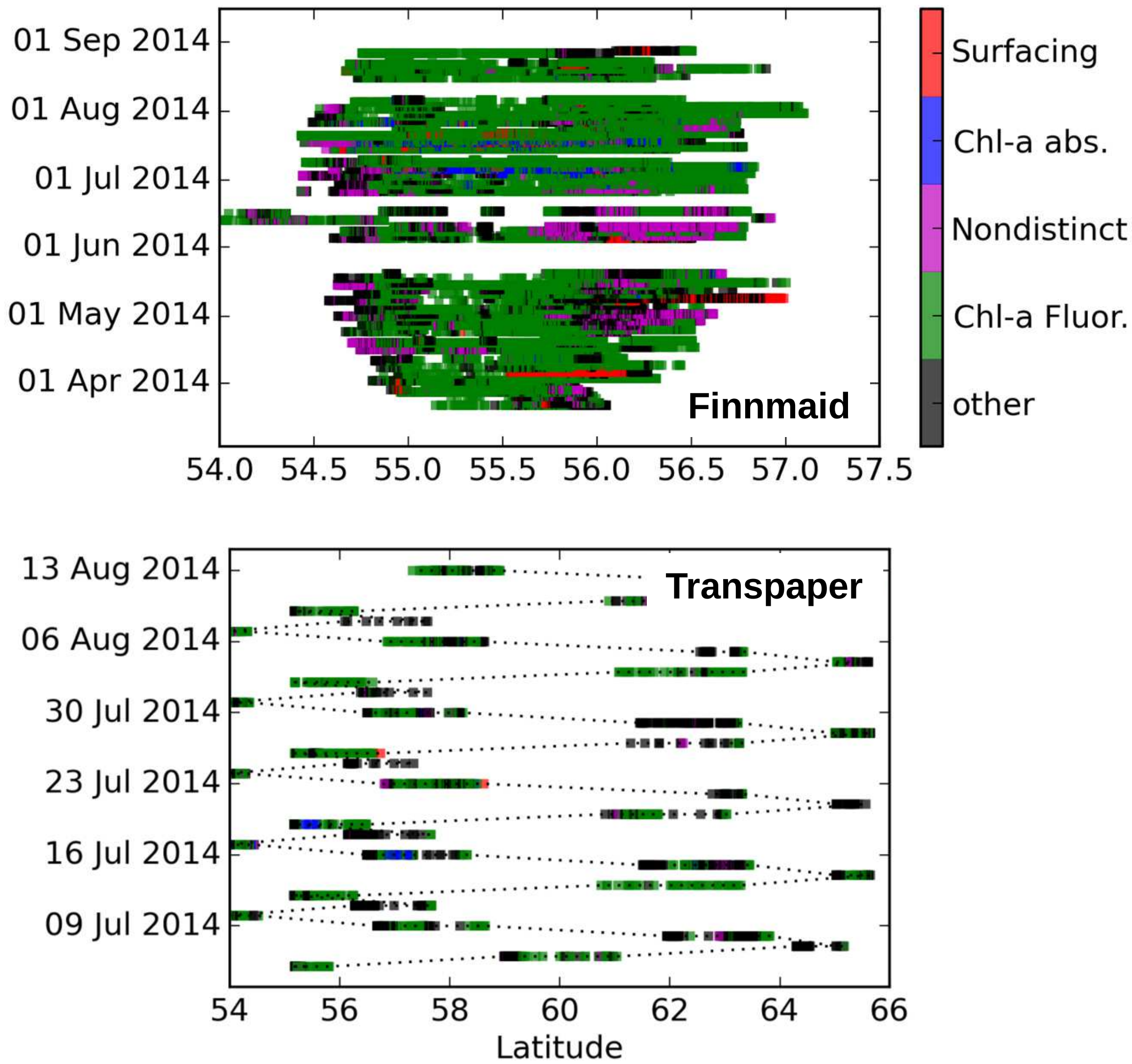
First processing 2014



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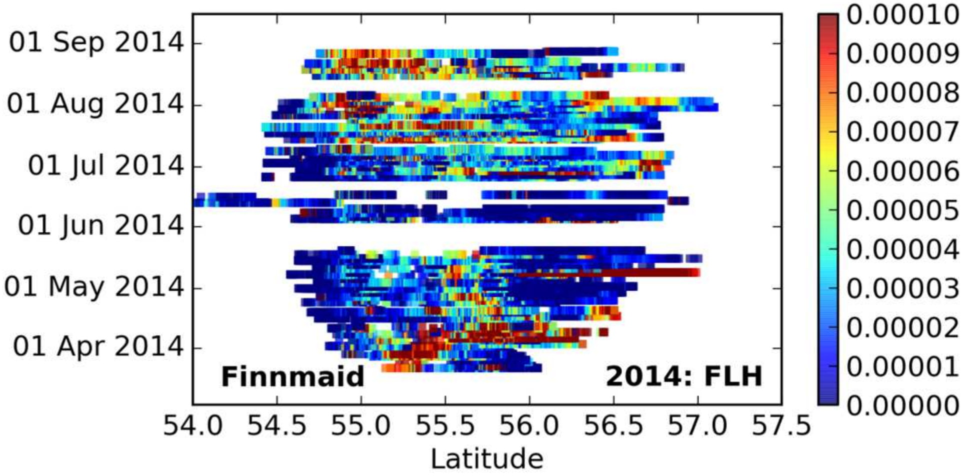
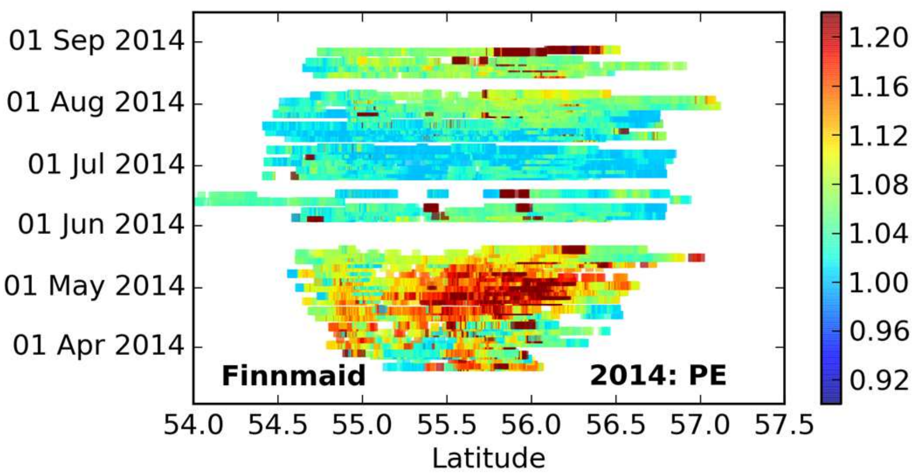
Quantitative processing 2014

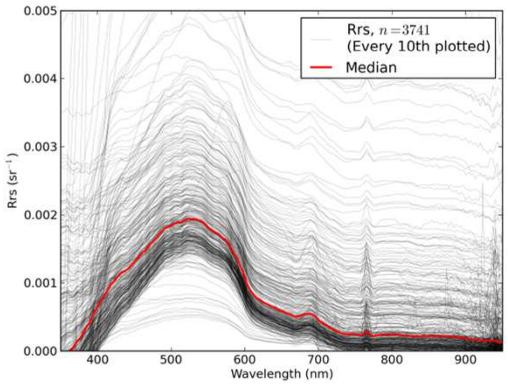


‘Fluorescence Line Height’
= Rrs(685) – Rrs(675)
targets Chl-a absorption
and fluorescence maxima



Phycoerythrin absorption at 560 nm:
Rrs(peak)-Rrs(780)
/ (Rrs(560) – Rrs780)

Spectra with PE index 1.11-1.20



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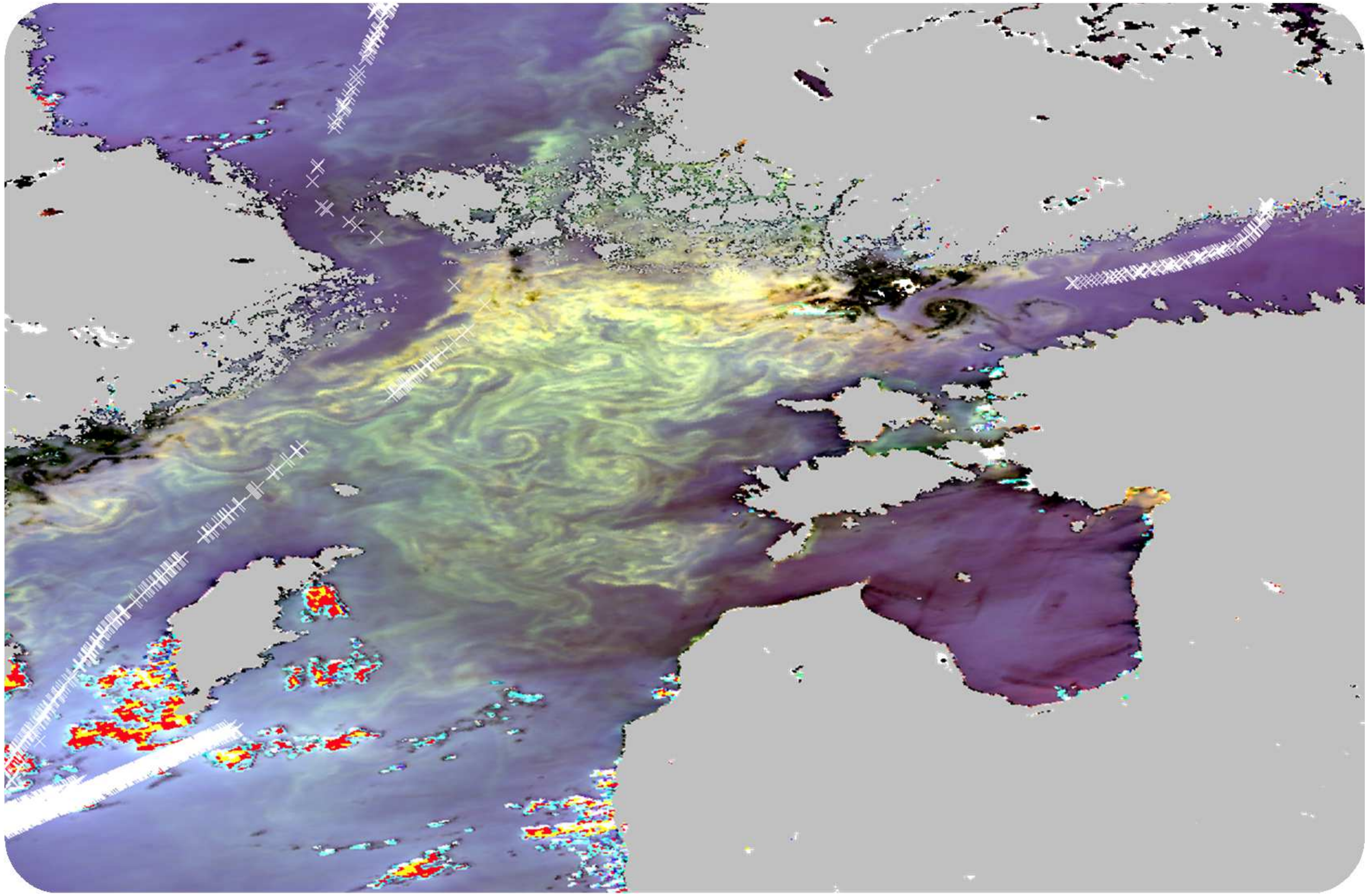
Summer 2014 surface scums in the Northern Baltic Proper and Archipelago Sea

R_{rs} coverage 2014: what we missed



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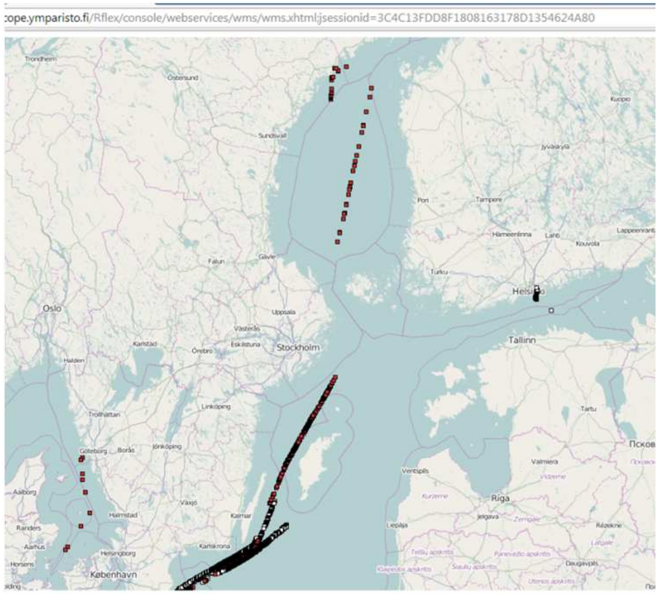
Data access

SYKE Rflex Rrs WFS / WMS
are online, user feedback welcome!

http://ferryscope.ymparisto.fi/Rflex/



Choose: wfs ▾ General ▾ wfs/General/GetFeature_Filter_Examples/xml/ByBBOX.xml ▾

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URL: http://ferryscope.ymparisto.fi:80/Rflex/services/ RflexWFS ▾ send

download response


```
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<!--NOTE: numberReturned attribute should be 'unknown' as well, but this would not validate against the current version of the WFS 2.0 schema (change upcoming). See change request (CR 144): https://portal.opengeospatial.o
  <wfs:member>
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```


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Summary

Ship-based R_{rs} provides an interface between remote and in-water (flow-through) observations. Now we can:

- **Solve conflicts** between data sources e.g. caused by shallow mixing
- **Flag surface accumulations**, exclude these from RS processing
- Use **hyperspectral reflectance spectroscopy** to identify pigment absorption signatures (provided sufficient biomass)
- Address **atmospheric correction** issues – solve atmospheric contribution to remotely sensed signal from *in situ* water-leaving reflectance

- Let’s build a network! (1) Join FerryScope; (2) Build and Install Rflex; (3) Get your data fully processed and matched with EO imagery. Let’s share!

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Have ship? Add Rflex module ->

Now serving: $R_{rs}(\lambda)$ through WFS/WMS on
http://ferryscope.ymparisto.fi/Rflex/

Matchups, timeseries, etc:
join the FerryScope user base
http://www.ferryscope.org/

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FerryScope

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